Project Report

Suwannee River water Management Area 5 LiDAR Florida State Plane North

Prepared For:

United States Geological Survey

Prepared By:

Digital Aerial Solutions, LLC

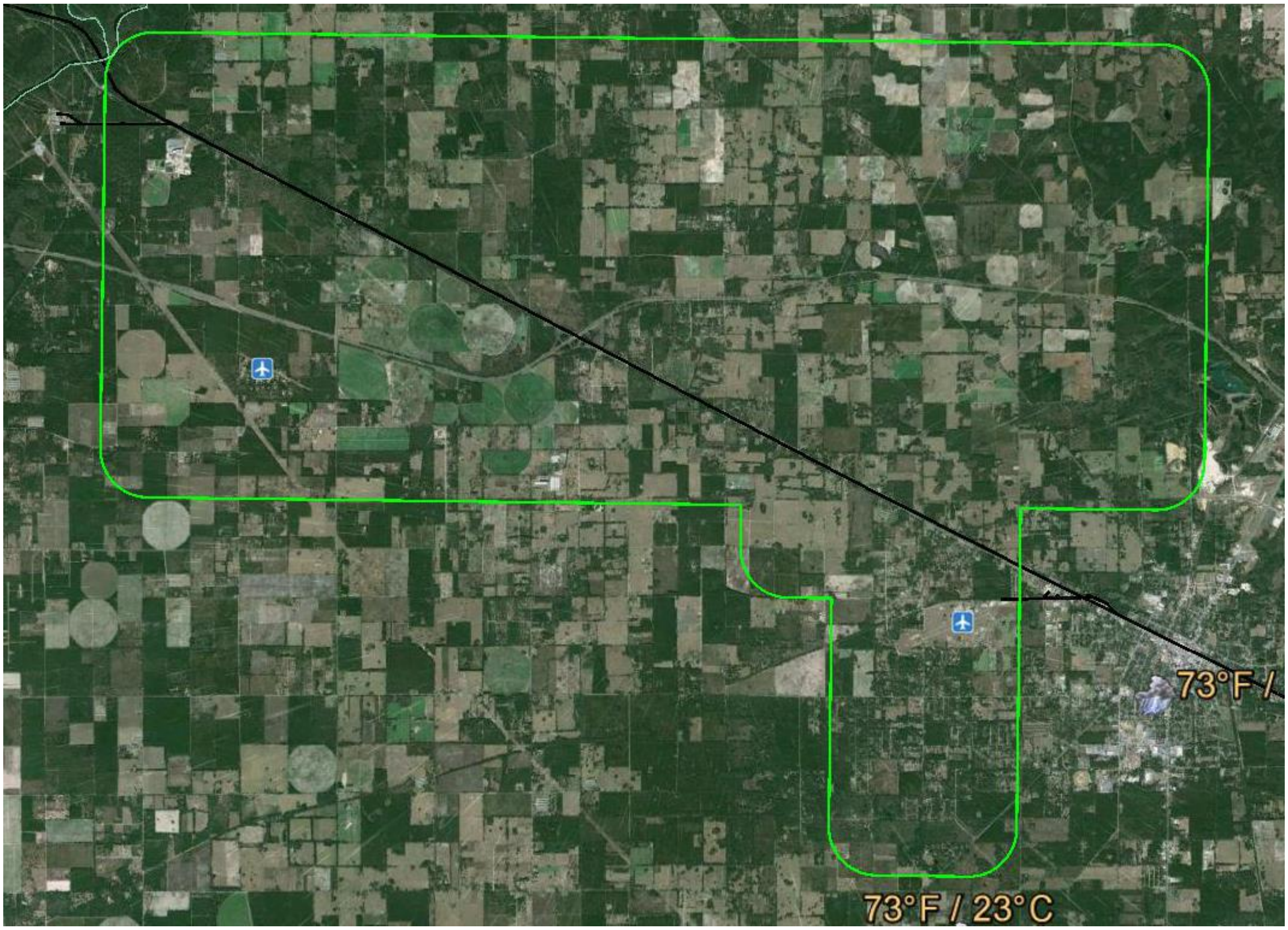
CONTRACT: #G10PC00093
CONTRACTOR: DIGITAL AERIAL SOLUTIONS
TASK ORDER: #G12PD00242

Project Report
LiDAR Collection, Processing, and QA/QC

2012 Suwannee Management LiDAR Task Order

Prepared For:
US Geological Survey
1400 Independence Road
Rolla, MO 65401
Phone: (573) 308-3587

Prepared By:
Digital Aerial Solutions, LLC
8409 Laurel Fair Circle, Suite 100
Tampa, FL 33610
Phone: (813) 628-0788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1 Introduction and Specifications

Digital Aerial Solutions, LLC (DAS) was tasked to collect and process a Light Detection And Ranging (LiDAR) derived elevation dataset for the Suwannee Management, FL. The Suwannee Management survey area encompasses approximately 54 square miles. Aerial LiDAR data was collected utilizing an ALS60. The ALS60 is a discrete return topographic LiDAR mapping system manufactured by Leica Geosystems. LiDAR data collected for the Suwannee Management survey has a nominal pulse spacing of 0.9 meters, and includes up to 4 discrete returns per pulse, along with intensity values for each return.

LiDAR datasets were post processed to generate elevation point cloud swaths for each flight line. Deliverables include the point cloud swaths, tiled point clouds classified by land cover type, breaklines to support hydro-flattening of digital elevation models (DEM)s, and bare-earth DEM tiles. Point cloud deliverables are stored in the LAS version 1.2 format, point data record format 1. The tiling scheme for tiled deliverables is a 4900 Feet x 4900 Feet. All deliverables were generated in conformance with the *U.S. Geological Survey National Geospatial Program Guidelines and Base Specifications, Version 1.*

2 Spatial Reference System

The spatial reference of the data is as follows.

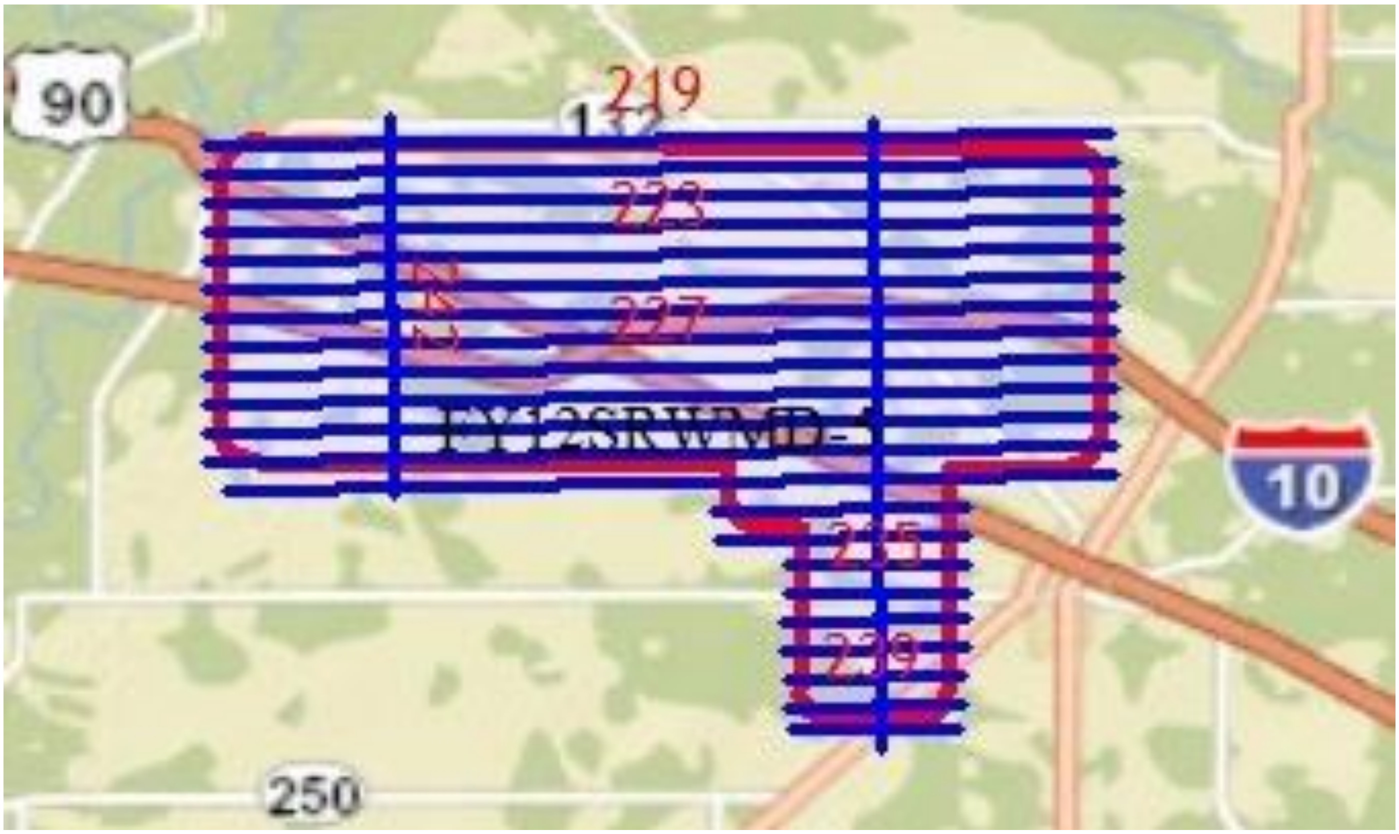
Horizontal Spatial Reference
- Datum: North American Datum of 1983 (National Spatial Reference System 2007)
- Coordinates: State Plane Florida North

Vertical Spatial Reference
All datasets are available with orthometric elevation; point cloud datasets are also available with ellipsoid heights
- Datum: North American Vertical Datum of 1988 (GEOID09)

3 LiDAR Acquisition

3.1 Survey Area

The Suwannee Management Area 5 survey covers approximately 64 square miles located in north central Florida. The flight plan consisted of 22 survey lines and
2 control lines.



3.2 Acquisition Parameters

Acquisition parameters include the sensor configuration and the flight plan characteristics, and are selected based on a number of project specific criteria. Criteria reviewed include the required accuracies for the final dataset, the land cover types within the project survey area, and the required nominal pulse spacing. Acquisition parameters selected for the Suwannee River water Management Area 5 LiDAR project are summarized below.

Parameter	Value
Flying Height Above Ground Level	5,575 feet
Nominal Sidelap	30%
Nominal Speed Over Ground	140 knots
Field of View	30°
Laser Rate	200 kHz
Scan Rate	68.4 hz
Maximum Cross Track Spacing	0.98 meters
Maximum Along Track Spacing	0.98 meters
Average Spacing	1 meter

3.3 Acquisition Mission

The acquisition mission for the Suwannee Management Area 5 LiDAR survey was coordinated to be acquired in 1 week. Collection began on January 19th 2013 and was completed on January 20th, 2013, A complete flight log for the acquisition mission may be found in Appendix A.

3.4 Airborne GPS/IMU

Airborne global positioning system (GPS) and inertial measurement unit (IMU) data was collected on the aircraft during the acquisition mission, providing sensor position and orientation information for geo-referencing the LiDAR data. Airborne GPS observations were collected at a frequency of 2Hz, and IMU observations are collected at a frequency of 200Hz.

Aircraft	Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
C421 – N112MJ	ALS60 – SN6130	x: -0.210, y: -0.060, z: -1.370	x: -0.450, y: -0.159, z: -0.169

In addition, GPS data was collected with ground base stations during the acquisition mission, providing corrections to support differential post-processing of the airborne GPS. One ground base station was setup at an NGS Benchmark (Keyport) as the base of operation. The additional ground base station were selected and place threw the project to ensure complete coverage. Ground GPS observations were collected at a frequency of 2Hz.

4 LiDAR Processing

4.1 Acquisition Post-Processing

Once the acquisition was completed, initial post-processing was performed to generate geo-referenced LiDAR elevation point clouds.

The airborne GPS dataset was differentially corrected using the ground base station GPS datasets collected by DAS in Lecia's IPAS software. IPAS computes the GPS dataset corrections in both forward and reverse chronological sequence, obtaining two solutions for the GPS trajectory. The differences between these two solutions were reviewed to ensure a consistent result, and agree within +/- 3cm. The forward and reverse solutions also show good fit between the two different base stations used in the post-processing.

Differentially corrected airborne GPS data was merged with the airborne IMU dataset in Leica's IPAS software through Kalman filtering techniques. IPAS applies the reference lever arms for the GPS and IMU measurement systems during processing to determine the trajectory (position and orientation) of the LiDAR sensor during the acquisition mission. Estimated lever arm values reported posteriori validate the measurements made during sensor installation in the aircraft.

Raw LiDAR sensor ranging data and the final sensor trajectory from IPAS were processed in Leica's ALSPP software to produce the LiDAR elevation point cloud swaths for each flightline, stored in LAS version 1.2 file format. Quality control of the swath point clouds was performed to validate proper function of the sensor systems, full coverage of the project AOI, and point density consistent with the planned nominal pulse spacing. The LiDAR data collected for the Suwannee Management survey Area5 passed these quality control checks.
Swath point clouds were assigned a unique File Source ID within the LAS file format before further processing. Swath files for the Suwannee Management Area 5 LiDAR project were numbered in chronological order of acquisition.

4.2 Geometric Calibration

Geometric and positional accuracy of the LiDAR swath point clouds is highly dependent on accurate calibration of the various subsystems within the LiDAR sensor system. Sensor calibration parameters fall into two categories, one being those parameters proprietary to the manufacturer's sensor design, and the other being parameters common to most commercial airborne LiDAR sensors, the IMU to laser reference system alignment angles (bore-site), and mirror deformation constants (scaling).

The manufacturer specific calibration parameters are applied in Leica's ALSPP software for the ALS60 sensor system. Terrasolid's Terramatch software was used to calculate the IMU bore-site and mirror scale parameters for the Suwannee Management's Area 5 LiDAR data. Within the TerraMatch software, the Tie-line workflow was used to solve for the parameters. The Tie-line workflow involves automated selection of numerous 'tie-lines', which represent a linear segment fit to the data that should have the same slope, azimuth, position and elevation, within the overlap sections of the survey lines and control lines. The tie- lines provide observations for algorithms within TerraMatch to solve for the bore-site and mirror scale parameters for the lift.

The Tie-line workflow is dependent upon well distributed tie-lines throughout the swath point clouds to effectively solve for bore-site and mirror scale parameters with the automated algorithms. The Suwannee Management survey area did not support this requirement, due to the large water area within the survey and control lines. Manual estimation of the bore-site and mirror scale parameters was performed using the observed tie-lines in overlap areas.

The final step of geometric calibration is to determine elevation (z) offset corrections to be applied to the swath point clouds. Z values calculated during the course of the acquisition mission can vary at the centimeter level as the GPS satellite constellation observed in the survey area changes with satellites moving through their orbits over the course of the mission. Baseline length from the ground base station GPS to the airborne GPS can also impact the z values calculated for the swath point clouds. Z offset corrections are calculated in two steps; a relative step, where individual lines are corrected one to another using the adjusted tie-lines from the bore-site and mirror scale calculation step; and an absolute step, where groups of lines are leveled to project ground control.

For the Suwannee Management Area 5 LiDAR project, the control lines were used to determine relative z offset corrections in areas of discernible ground. The base station operated by DAS in the survey area provided for minimal baseline lengths, resulting in generally good z agreement between the survey lines and control lines.

The final geometrically calibrated swath point clouds were compared to the bare-earth profile survey data. The data fit the profile surveys within the vertical accuracy tolerance specified for the project. Full documentation of the vertical accuracy checks maybe found in section 5.1.

4.3 Point Cloud Classification

Georeference information was applied to the swath point could LAS files. Geometrically calibrated swath point clouds were cut into 4900 Feet x 4900 Feet LAS format tiles for point cloud classification and derived product creation. It is important to note that US National Grid tiles are non- orthogonal when stored and displayed in a geographic coordinate system. As a result, tiled vector data does not have overlap, but tiled raster data does have overlap to permit seamless display of the data products.

Tiled point cloud data was processed in Terrasolid's Terrascan software to assign initial classification values. The Terrascan software provides a number of routines to algorithmically detect and assign points to their appropriate class. Points left unclassified by the algorithmic routine remain as Class 1 – Processed, but unclassified. Automated classification routines assigned points to one of the following classes:

- Class 1 – Processed, but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Noise
- Class 9 – Water
- Class 10 – Ignored Ground
- Class 11 – Withheld
- Class 17 – Reserve
- Class 18 – Reserve

Automated classification results were reviewed for each tiled point cloud, and manual edits made where necessary to correct for misclassified points. Points remaining in Class 1 after the automated classification routines were run were left in Class 1. Points falling outside of a 105 meter buffer of the project AOI polygon were excluded from the tiled point clouds.

4.4 Breakline Collection

Manual breakline collection was performed to support the hydro-flattening requirements of the project's DEM deliverables. Breaklines were collected directly from the classified point clouds and from triangulated irregular network (TIN) surface models built from the classified point clouds, in Terrasolids's Terrascan and Terramodeler software. Breakline features were collected as design file elements in Bentley's Microstation software. Breaklines were converted to ESRI 3D shapefile format for the breakline deliverable, and tiled to the project US National Grid index.

The data collected for the Suwannee Management LiDAR Area 5 survey maintained significant point density in the water, marsh, and swamp, limiting the usefulness of point density as guiding factor in breakline placement.

Points classified as Class 2 – Bare-earth ground, falling within a one meter buffer of the collected breaklines, were reassigned to Class 10 – Ignored Ground. These points are excluded from the surface model during DEM generation to preserve the hydro-flattening characteristics of the breaklines.

4.5 DEM Generation

The final classified point clouds and collected breaklines were reviewed for completeness and conformance to the task order scope of work and the NGP version 1 guidelines. Within the Terramodeler software, points in Class 2 – Bare-earth ground and the breaklines were combined to generate TIN elevation models for each tile, from which the bare-earth DEM tiles were interpolated and exported as 32 bit float Arc Grid.

5 Quality Control

5.1 Point Clouds

Accuracy and completeness of the LiDAR point clouds directly impacts the quality of all other derived LiDAR derived products. Ensuring a quality LiDAR dataset begins with proper mission planning and execution. Ground GPS base stations are located such that GPS baselines between the ground and airborne receivers do not exceed 30km. For the Suwannee Management LiDAR project, two base stations were run to meet this requirement, one at the field operations airport and one within the survey area. Static alignment is performed both before take-off and after landing to allow for GPS integer ambiguity resolution. Sensor operators carefully monitor the LiDAR unit and its various subsystems during the acquisition mission to ensure proper function. Airborne GPS positional dilution of precision (PDOP) estimates are monitored to ensure they remain less than 3.The optical system is monitored to ensure there are no ranging errors encountered during the flight lines.

During acquisition post-processing estimates of the trajectory data accuracy are reviewed to ensure they will support the required accuracies of the point cloud data. The trajectory accuracy is a function of the differentially corrected GPS data and the IMU data.

The raw swath point clouds generated from ALSPP are reviewed as another check for proper sensor function. The point clouds are reviewed for full coverage of the AOI, required point density and nominal pulse spacing, clustering, proper intensity values, full swath coverage within the planned field of view, and planned survey line overlap.

Geometric calibration quality control validates that the positional accuracy requirements of the project are met, and includes relative accuracy assessments for intra-swath (within) and inter-swath (between) accuracy, along with absolute accuracy assessments against project ground control.

Relative vertical accuracy assessments are normally made using the tie-lines generated in the Terramatch software, as these lines provide positional observations throughout the extent of individual swaths, and between neighboring swaths.

Horizontal accuracy assessments of LiDAR data require the presence of vertical targets such as buildings within in the survey area. Field check points are surveyed at the corners of the building roofs, and the surveyed locations compared to the estimated corner locations in the LiDAR point cloud. The Suwannee Management survey area did not present any accessible buildings for use as vertical targets. From the manufacturer's specifications, the estimated horizontal accuracy at one sigma, based on flying height for the project, is between 10cm and 20cm.

Absolute vertical accuracy assessments for the point cloud data are made against ground check point data. For the Suwannee Management Area 5 survey, ground check point data consisted of the ground GPS base station, and real-time kinematic (RTK) GPS techniques.

Check point locations were collected at 1 – second intervals during the RTK survey. Points collected during the static pre-initialization and post-initialization were removed from the assessment so as not to bias the assessment.

Local TIN models of the elevation points are built around each ground check points. The tin model elevation is sampled at the horizontal position of the ground check point. The TIN model elevation and ground check point survey elevation values were used to calculate the fundamental vertical accuracy (FVA) of the swath point clouds as described in NDEP Elevation Guidelines Version 1. The FVA of the TIN tested RMSEz 0.095 Feet and 0.183 Feet at the 95% confidence level in open terrain. FVA of the DEM tested at an RMSEz of 0.095 Feet and 0.187 Feet at the 95% confidence level in open terrain. The full calculations for all check points can be found in Appendix B.

FVA of TIN

$RMSE_Z$ =	0.095	Feet
NSSDA=	0.183	Feet

FVA of DEM

$RMSE_Z$ =	0.095	Feet
NSSDA=	0.187	Feet

The tiled point cloud products were reviewed for full coverage of the AOI and proper classification. As part of the QC process, TINs are built in the Terramodeler software for each tile using the ground class and the hydro-flattening breaklines. The TINs are reviewed for non-ground features, and edited where necessary to remove any remaining non-ground features. Points were also reviewed for absolute elevation, and points falling below the selected orthometric elevation for water were removed from the ground class.

5.2 Breaklines

The final breaklines in ESRI 3D shapefile format were reviewed for topological consistency and correct elevation. Breaklines features are continuous and do not have overlaps or dangles.

5.3 Digital Elevation Models

Digital elevation models (DEMs) were reviewed for conformance with the SOW and the NGP version 1 guidelines. DEM files were loaded in the Global Mapper software and inspected visually for edge matching between tiles, void areas within the project AOI, and proper coding of the NODATA values. DEM file naming was verified for consistency with the US National Grid tile index.

Appendix A. Flight Logs

ALS60 LiDAR Flight Log

Project	**Suwannee 2013**	**ALS60**	N6130_090724		**Sensor Operator/s**
				-	Bertin Evina-Ze
Date/Julian:	1/192013 Suwannee	**Mem Drive MM60**	**Int. Time:**	**TAR AIRSPD (KNTS)**	**Base PID:**	**Pilot/s**
Hobbs End	656.3	6-600110120		140	BD2735	Weazel
Hobbs ST	656.3	**LIFT B**	**TAR ALT AGL (ft):**	**Flight Plan(s):**	**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time	0.0		5,575	Block 5	1.500	421C 112MJ	24J

Lift		Flight Line	Mission Line	UTC time: B:	E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	HDOP	Comments and Conditions:
A						-	-	-	88				Static Alignment
		219	130119_195009	19:50	19:54	5,600	270	139	87	17	1.4	0.7	CLEAR
		220	130119_195828	19:58	20:02	5,622	90	138	86	17	1.4	0.7	CLEAR
		221	130119_200708	20:07	20:11	5,626	270	132	85	18	1.3	0.7	CLEAR
		222	130119_201501	20:15	20:19	5,633	90	143	84	18	1.1	0.6	CLEAR
		241	130119_202824	20:28	20:30	5,654	0	137	83	18	1.1	0.6	X STRIP
		241	130119_203913	20:39	20:41	5,642	180	142	83	18	1.1	0.6	X STRIP
		242	130119_204553	20:45	20:48	5,620	0	142	82	18	1.0	0.6	X STRIP
		242	130119_205157	20:51	20:53	5,618	180	124	82	18	1.0	0.6	X STRIP

ALS60 LiDAR Flight Log

Project	**Suwannee 2013**	**ALS60**	N6130_090724		**Sensor Operator/s**
				-	Meagan McCall
Date/Julian:	1/20/2013 Suwannee	**Mem Drive MM60**	**Int. Time:**	**TAR AIRSPD (KNTS)**	**Base PID:**	**Pilot/s**
Hobbs End	656.3	6-600110120		140	BD2735	MWAZ
Hobbs ST	653.3	**LIFT A**	**TAR ALT AGL (ft):**	**Flight Plan(s):**	**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time	3.0		5,575	Block 5	1.500	421C 112MJ	24J

Lift		Flight Line	Mission Line	UTC time: B:	E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	HDOP	Comments and Conditions:
A						-	-	-	81				Static Alignment
		223	130120_154725	15:47	15:52	5,532	270	131	80	15	1.2	0.7	CLEAR
		224	130120_155600	15:56	16:00	5,534	90	142	79	15	1.2	0.7	CLEAR
		225	130120_160430	16:04	16:09	5,530	270	133	78	15	1.3	0.7	CLEAR
		226	130120_161256	16:12	16:17	5,537	90	139	77	15	1.2	0.7	CLEAR
		227	130120_162116	16:21	16:26	5,531	270	132	76	14	1.3	0.7	CLEAR
		228	130120_162931	16:29	16:34	5,536	90	139	75	15	1.1	0.7	CLEAR
		229	130120_163728	16:37	16:42	5,530	270	131	73	16	1.1	0.7	CLEAR
		230	130120_164530	16:45	16:49	5,539	90	144	72	15	1.3	0.8	CLEAR
		231	130120_165317	16:53	16:57	5,519	270	134	71	15	1.3	0.8	CLEAR
		242	130120_170134	17:01	17:03	5,538	0	146	70	16	1.2	0.7	X STRIP
		242	130120_170750	17:07	17:10	5,520	180	119	70	16	1.2	0.7	X STRIP
		232	130120_171814	17:18	17:19	5,555	90	138	69	16	1.3	0.7	CLEAR
		233	130120_172318	17:23	17:24	5,508	270	130	69	17	1.3	0.7	CLEAR
		234	130120_172835	17:28	17:29	5,503	90	140	69	17	1.2	0.6	CLEAR
		235	130120_173314	17:33	17:34	5,482	270	138	68	17	1.2	0.6	CLEAR
		236	130120_173731	17:37	17:38	5,532	90	138	68	17	1.2	0.7	CLEAR
		237	130120_174309	17:43	17:44	5,510	270	138	68	17	1.3	0.7	CLEAR
		241	130120_175047	17:50	17:54	5,537	0	140	67	16	1.4	0.7	X STRIP
		241	130120_175805	17:58	18:02	5,563	180	129	67	17	1.2	0.6	X STRIP

DAS Digital Aerial Solutions

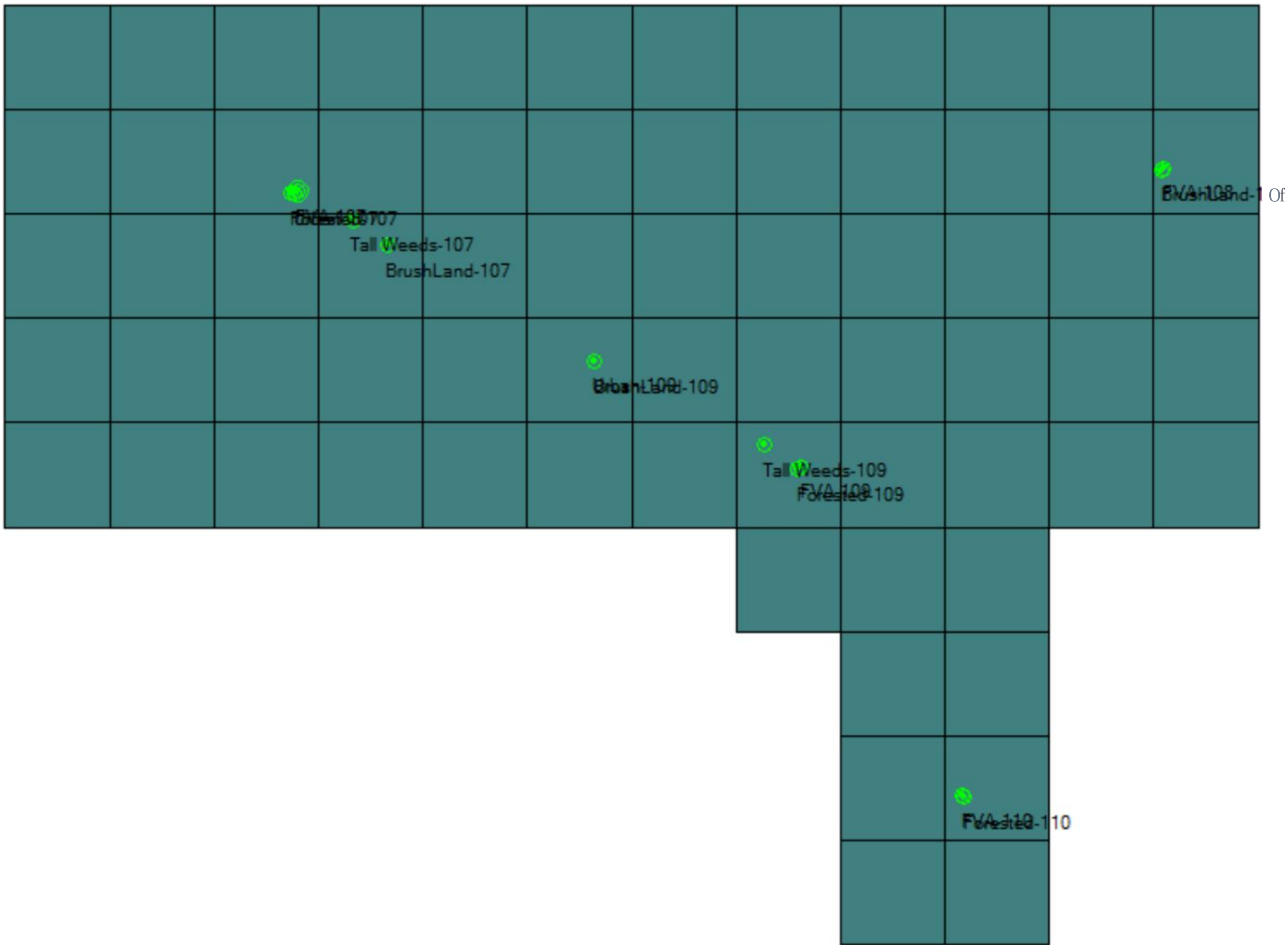
ALS60 LiDAR Flight Log

Project	Suwannee 2013	ALS60	N6130_090724				Sensor Operator/s
					-		Meagan McCall
Date/Julian:	1/20/2013 Suwannee	Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)		Base PID:	Pilot/s
Hobbs End	659.1	3-600093051		140		BD2735	MWAZ
Hobbs ST	656.3	LIFT B		TAR ALT AGL (ft):	Flight Plan(s):	Base Height:	Aircraft / Airport Idnt:
Flight Time	2.8			5,575	Block 5 and Block 4	1.500	421C 112MJ / 24J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B						-	-	-	149				Static Alignment
Block 5		238	130120_231412	23:14	23:16	5,616	90	143	148	16	1.2	0.6	CLEAR
		239	130120_232014	23:20	23:21	5,624	270	127	148	16	1.2	0.6	CLEAR
		240	130120_232440	23:24	23:25	5,591	90	137	148	17	1.1	0.6	CLEAR
		241	130120_232954	23:29	23:31	5,616	0	133	147	17	1.1	0.6	X STRIP
		241	130120_233446	23:34	23:36	5,592	180	137	147	18	1.0	0.6	X STRIP
Block 4		205	130120_234209	23:42	23:46	5,633	270	132	146	19	1.0	0.6	CLEAR
		206	130120_235018	23:50	23:54	5,624	90	138	145	16	1.2	0.7	CLEAR
		207	130121_000012	00:00	00:04	5,703	270	132	144	15	1.3	0.7	CLEAR
		208	130121_001355	00:13	00:18	5,720	90	140	142	16	1.2	0.6	CLEAR
		209	130121_002342	00:23	00:28	5,674	270	134	141	16	1.2	0.6	CLEAR
		210	130121_003200	00:32	00:36	5,695	90	140	140	16	1.2	0.7	CLEAR
		211	130121_004209	00:42	00:46	5,687	270	132	139	17	1.1	0.6	CLEAR
		212	130121_005038	00:50	00:55	5,705	90	139	138	16	1.1	0.6	CLEAR
		213	130121_005901	00:59	01:03	5,697	270	133	136	18	1.0	0.6	CLEAR
		214	130121_010718	01:07	01:11	5,644	90	142	135	16	1.2	0.7	CLEAR
		215	130121_012359	01:23	01:28	5,607	270	136	134	16	1.3	0.7	CLEAR
		216	130121_013156	01:31	01:36	5,580	90	142	133	16	1.3	0.7	CLEAR
		217	130121_014035	01:40	01:45	5,565	270	138	132	16	1.4	0.8	CLEAR
		218	130121_015019	01:50	01:52	5,590	0	139	131	16	1.5	0.8	X STRIP
		218	130121_015648	01:56	01:59	5,567	180	139	131	17	1.2	0.7	X STRIP

Appendix B. Vertical Accuracy Calculations

Tiled-Data Area



LC Type	# of Points	FVA	SVA	CVA
LAS				
ALL	14			0.561
FVA	4	0.183		
Urban	2		0.160	
Tallweeds	2		0.561	
Brushland	3		0.528	
Forested	3		0.380	
Total	14			
DEM				
ALL	14			0.521
FVA	4	0.187		
Urban	2		0.177	
Tallweeds	2		0.508	
Brushland	3		0.495	
Forested	3		0.400	
Total	14			

Units: Feet

Coordinates and Offsets of Analyzed Locations

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
1)	☑	FVA-107					
			295191.325	3360816.703	27.237	27.278	27.273
					0.041	0.036	FVA
2)	☑	FVA-108					
			307643.188	3361153.813	47.077	47.045	47.033
					-0.032	-0.044	FVA
3)	☑	FVA-109					
			302436.397	3356866.002	31.019	31.012	31.015
					-0.007	-0.004	FVA
4)	☑	FVA-110					
			304750.853	3352142.705	29.524	29.498	29.528
					-0.026	0.004	FVA
5)	☑	Urban-107					
			295153.619	3360794.898	27.25	27.254	27.23
					0.004	-0.02	Urban
6)	☑	Urban-109					
			299461.539	3358390.297	28.494	28.437	28.444
					-0.057	-0.05	Urban
7)	☑	Tall Weeds-107					
			295994.222	3360404.695	23.867	23.868	23.864
					0.001	-0.003	Tallweeds

Coordinates and Offsets of Analyzed Locations (Continued)

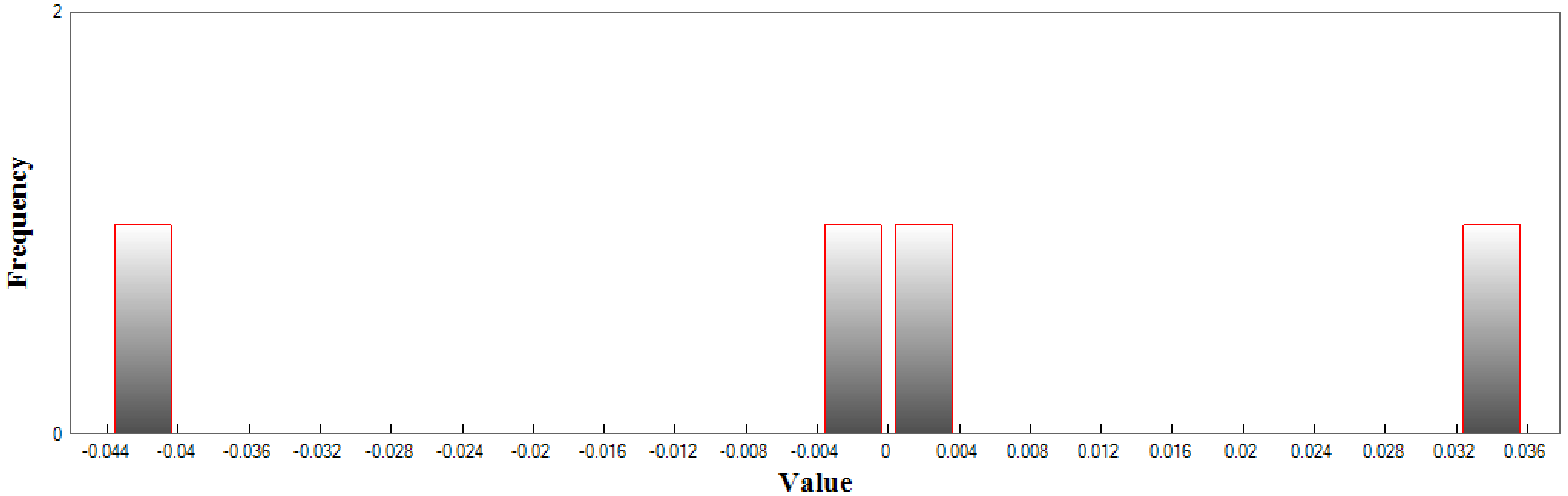
		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
8)	☑	Tall Weeds-109					
			301916.828	3357179.567	27.576	27.739	27.756
					0.163	0.18	Tallweeds
9)	☑	BrushLand-107					
			296485.908	3360047.168	22.283	22.38	22.395
					0.097	0.112	Brushland
10)	☑	BrushLand-108					
			307626.537	3361134.794	46.98	47.136	47.146
					0.156	0.166	Brushland
11)	☑	BrushLand-109					
			299473.517	3358371.345	28.544	28.65	28.649
					0.106	0.105	Brushland
12)	☑	Forested-107					
			295112.528	3360795.763	26.989	27.117	27.112
					0.128	0.123	Forested
13)	☑	Forested-109					
			302386.241	3356827.779	31.512	31.568	31.55
					0.056	0.038	Forested
14)	☑	Forested-110					
			304775.726	3352121.497	29.192	29.258	29.248
					0.066	0.056	Forested

LAS

Fundamental Vertical Accuracy

LandCover Type: FVA
Minimum DZ: -0.144
Maximum DZ: 0.118
Mean DZ: -0.006
Mean Magnitude DZ: 0.485
Number Observations: 4
Standard Deviation DZ: 0.108
RMSE Z: 0.095
95% Confidence Level Z: 0.183
Units: Feet

Histogram



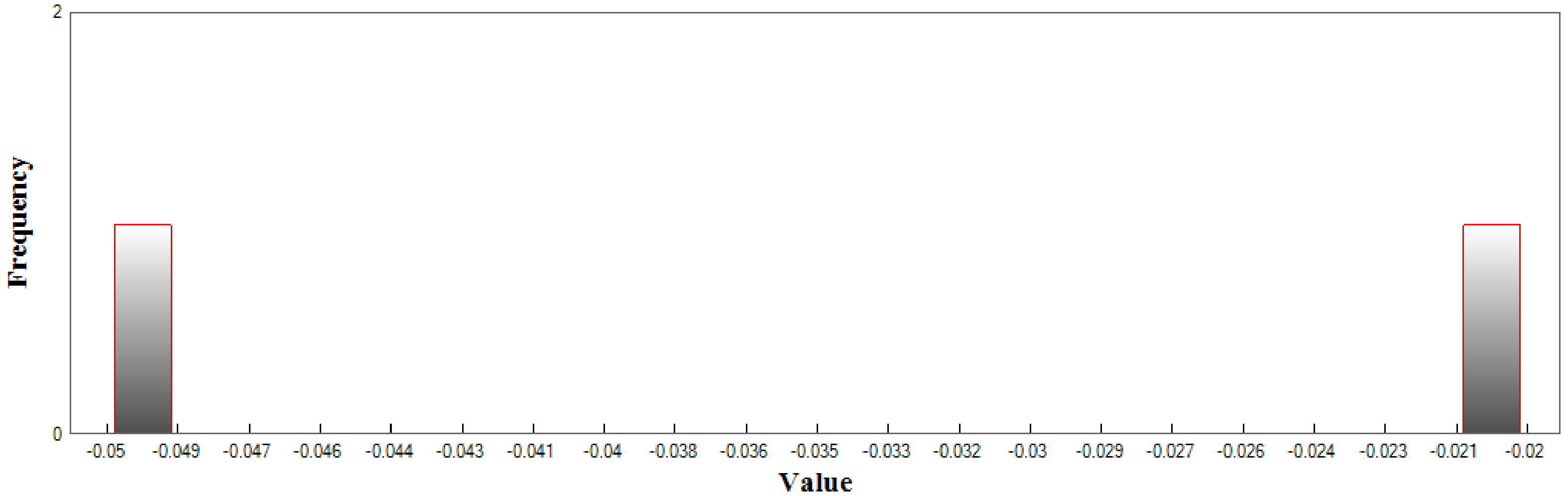
Min: -0.044
Max: 0.036
Number Of Bins: 20
Bin Interval: 0.004

LAS (Continued)

Supplemental Vertical Accuracy

LandCover Type: Urban
Minimum DZ: -0.164
Maximum DZ: -0.065
Mean DZ: -0.114
Mean Magnitude DZ: 0.616
Number Observations: 2
Standard Deviation DZ: 0.072
RMSE Z: 0.124
95th Percentile: 0.160
Units: Feet

Histogram



Min: -0.05
Max: -0.02
Number Of Bins: 20
Bin Interval: 0.002

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Tallweeds

Minimum DZ: -0.009

Maximum DZ: 0.590

Mean DZ: 0.291

Mean Magnitude DZ: 0.994

Number Observations: 2

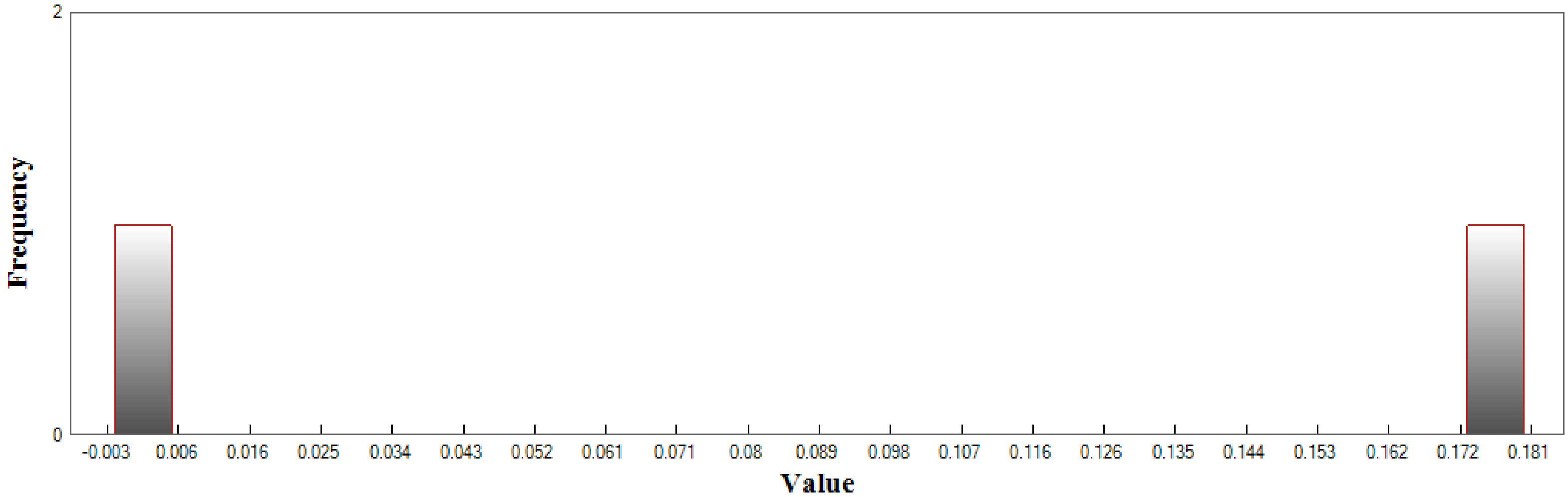
Standard Deviation DZ: 0.426

RMSE Z: 0.416

95th Percentile: 0.561

Units: Feet

Histogram



Min: -0.003

Max: 0.18

Number Of Bins: 20

Bin Interval: 0.009

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Brushland

Minimum DZ: 0.344

Maximum DZ: 0.544

Mean DZ: 0.419

Mean Magnitude DZ: 1.171

Number Observations: 3

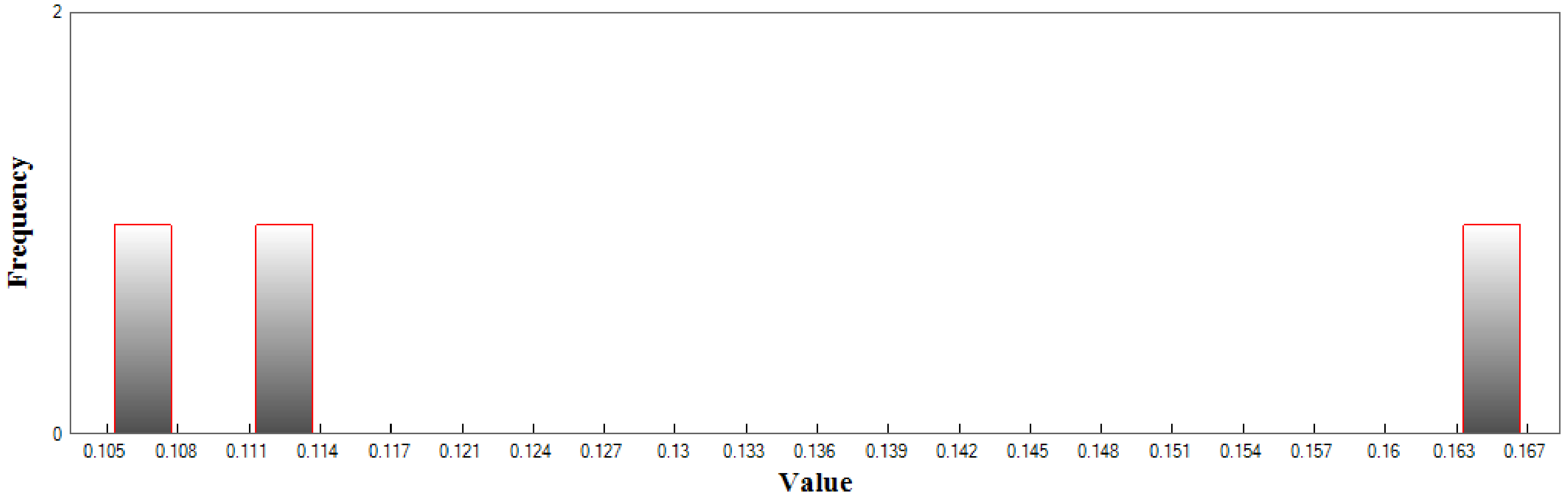
Standard Deviation DZ: 0.108

RMSE Z: 0.429

95th Percentile: 0.528

Units: Feet

Histogram



Min: 0.105

Max: 0.166

Number Of Bins: 20

Bin Interval: 0.003

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Forested

Minimum DZ: 0.124

Maximum DZ: 0.403

Mean DZ: 0.236

Mean Magnitude DZ: 0.882

Number Observations: 3

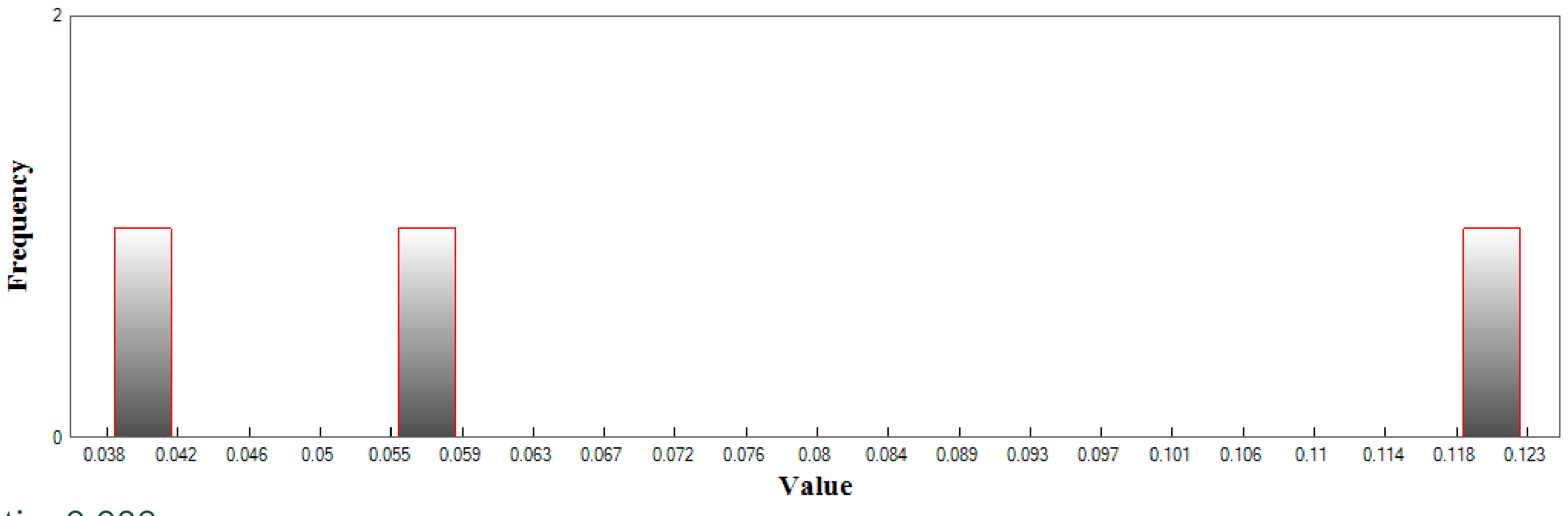
Standard Deviation DZ: 0.147

RMSE Z: 0.265

95th Percentile: 0.380

Units: Feet

Histogram



Min: 0.038

Max: 0.123

Number Of Bins: 20

Bin Interval: 0.004

LAS (Continued)

Consolidated Vertical Accuracy

LandCover Type: ALL

Minimum DZ: -0.164

Maximum DZ: 0.590

Mean DZ: 0.164

Mean Magnitude DZ: 0.849

Number Observations: 14

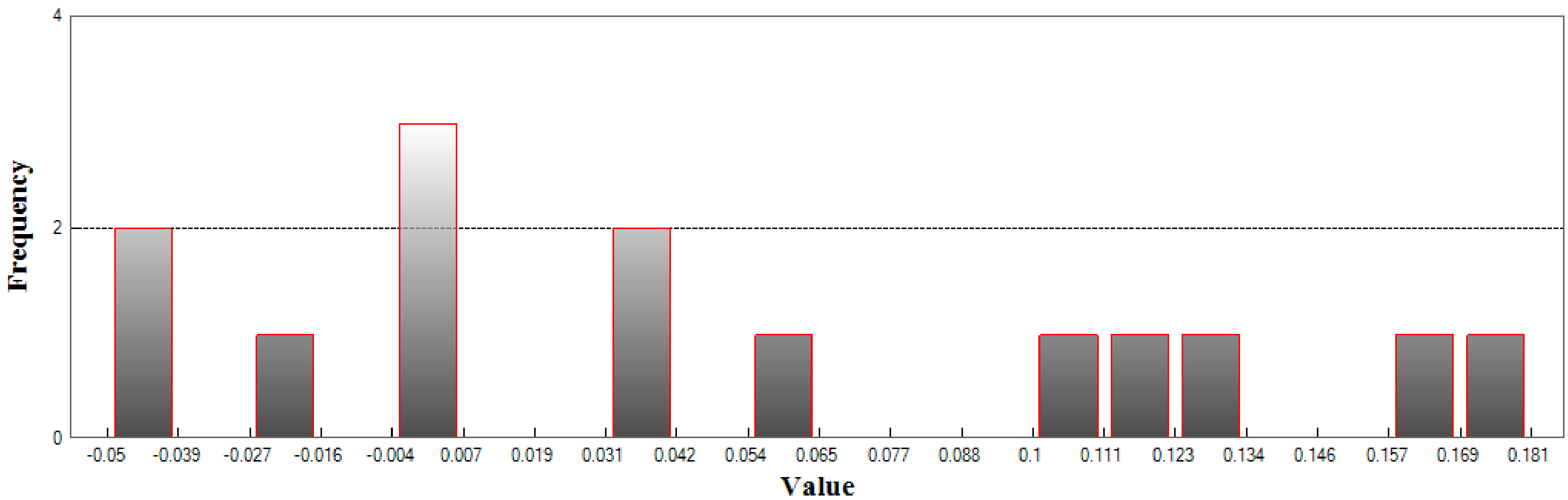
Standard Deviation DZ: 0.249

RMSE Z: 0.288

95th Percentile: 0.557

Units: Feet

Histogram



Min: -0.05

Max: 0.18

Number Of Bins: 20

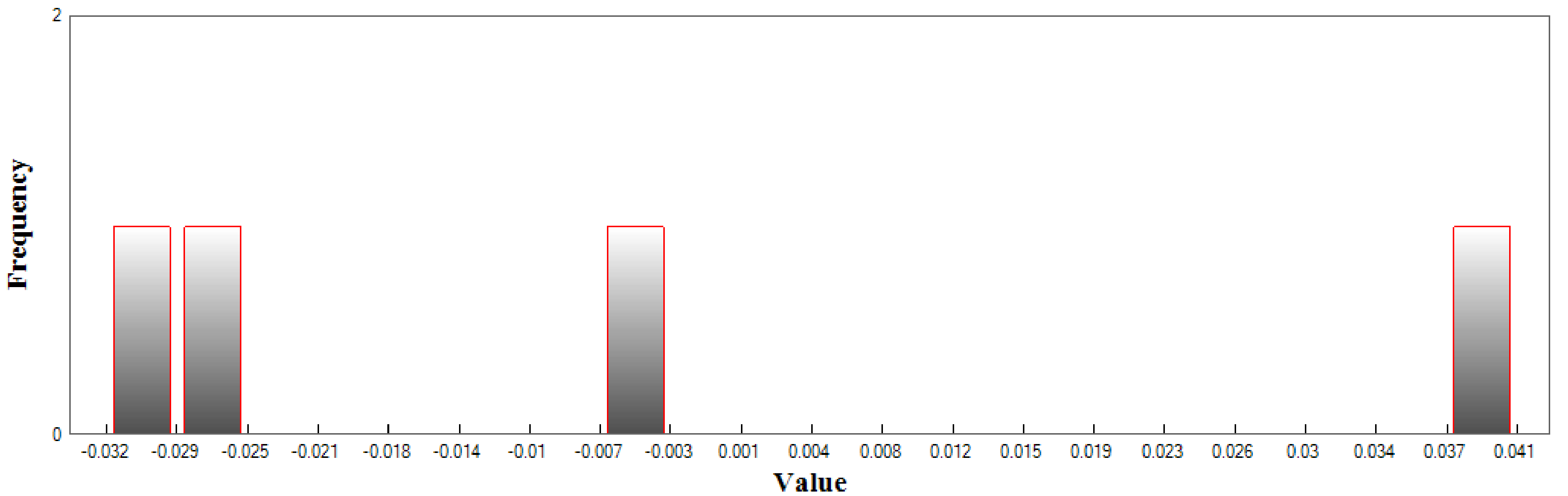
Bin Interval: 0.012

DEM

Fundamental Vertical Accuracy

LandCover Type: FVA
Minimum DZ: -0.104
Maximum DZ: 0.134
Mean DZ: -0.019
Mean Magnitude DZ: 0.534
Number Observations: 4
Standard Deviation DZ: 0.108
RMSE Z: 0.095
95% Confidence Level Z: 0.187
Units: Feet

Histogram



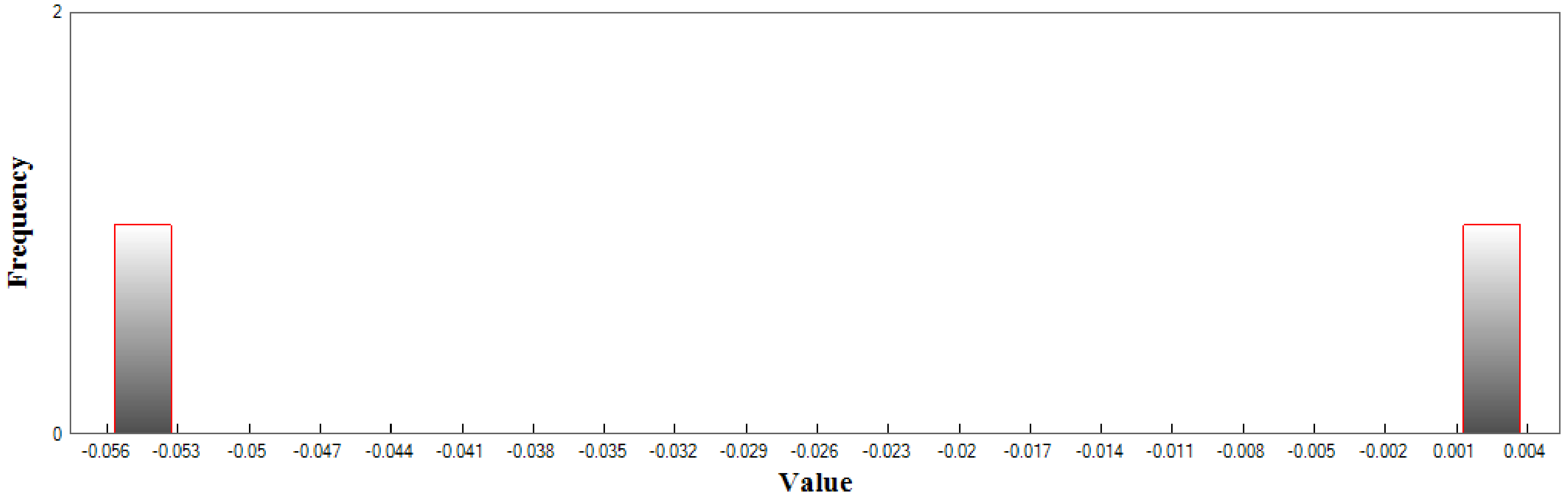
Min: -0.032
Max: 0.041
Number Of Bins: 20
Bin Interval: 0.004

DEM (Continued)

Supplemental Vertical Accuracy

LandCover Type: Urban
Minimum DZ: -0.187
Maximum DZ: 0.013
Mean DZ: -0.088
Mean Magnitude DZ: 0.570
Number Observations: 2
Standard Deviation DZ: 0.141
RMSE Z: 0.131
95th Percentile: 0.177
Units: Feet

Histogram



Min: -0.057
Max: 0.004
Number Of Bins: 20
Bin Interval: 0.003

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Tallweeds

Minimum DZ: 0.003

Maximum DZ: 0.534

Mean DZ: 0.269

Mean Magnitude DZ: 0.938

Number Observations: 2

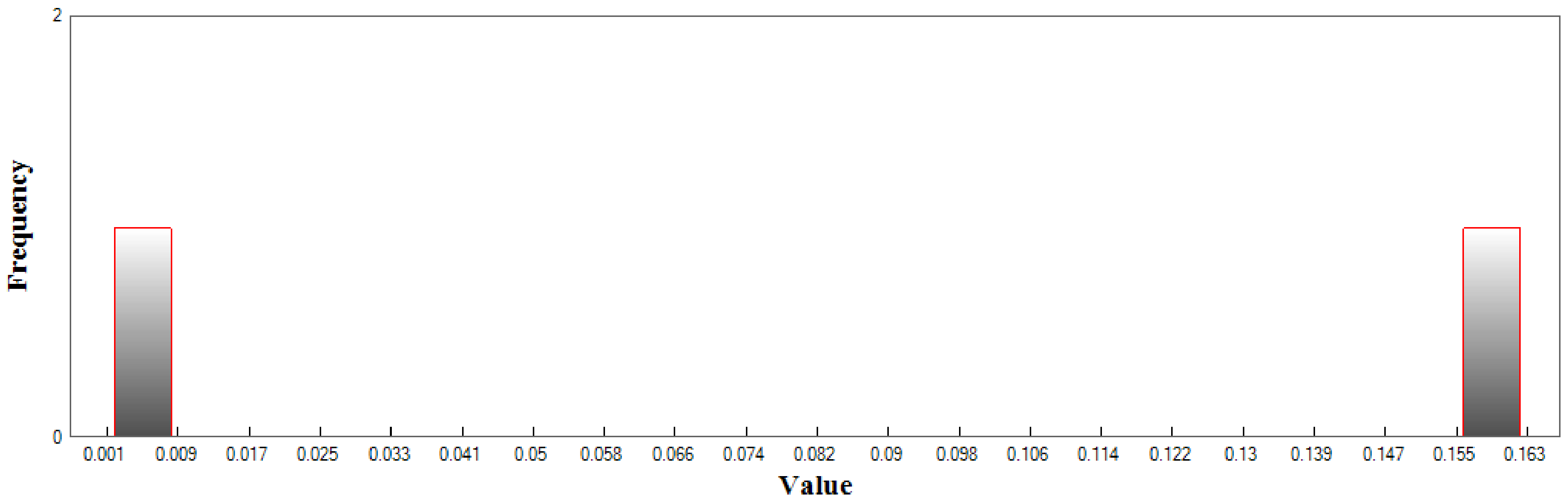
Standard Deviation DZ: 0.374

RMSE Z: 0.377

95th Percentile: 0.508

Units: Feet

Histogram



Min: 0.001

Max: 0.163

Number Of Bins: 20

Bin Interval: 0.008

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Brushland

Minimum DZ: 0.318

Maximum DZ: 0.511

Mean DZ: 0.393

Mean Magnitude DZ: 1.135

Number Observations: 3

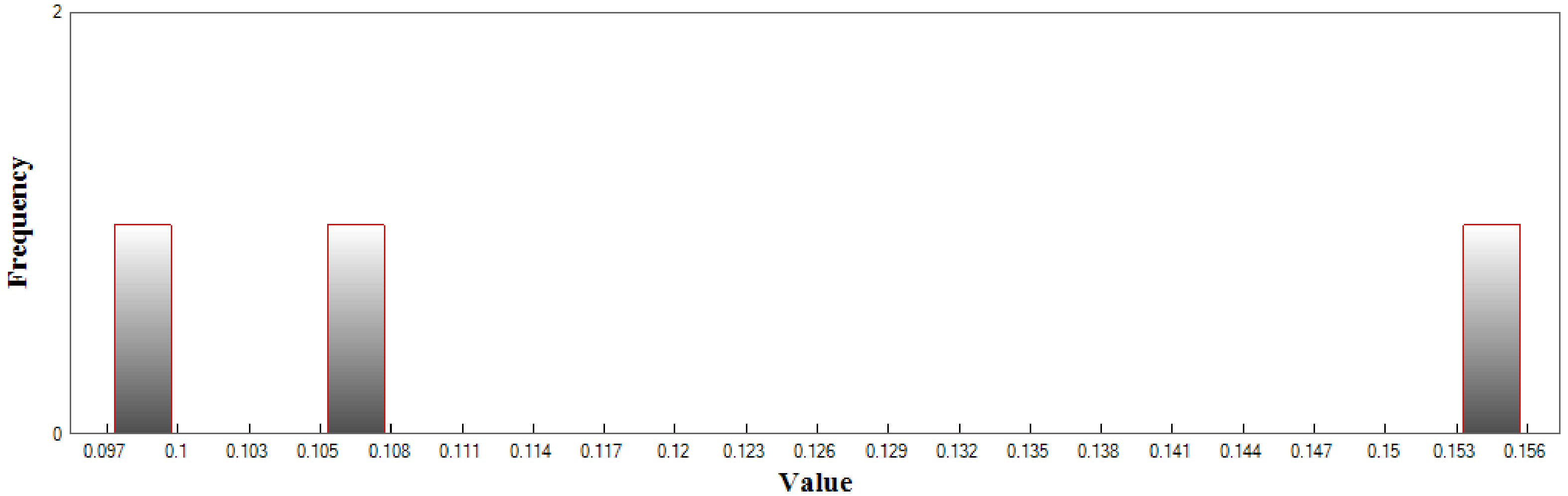
Standard Deviation DZ: 0.104

RMSE Z: 0.403

95th Percentile: 0.495

Units: Feet

Histogram



Min: 0.097

Max: 0.156

Number Of Bins: 20

Bin Interval: 0.003

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Forested

Minimum DZ: 0.183

Maximum DZ: 0.419

Mean DZ: 0.272

Mean Magnitude DZ: 0.948

Number Observations: 3

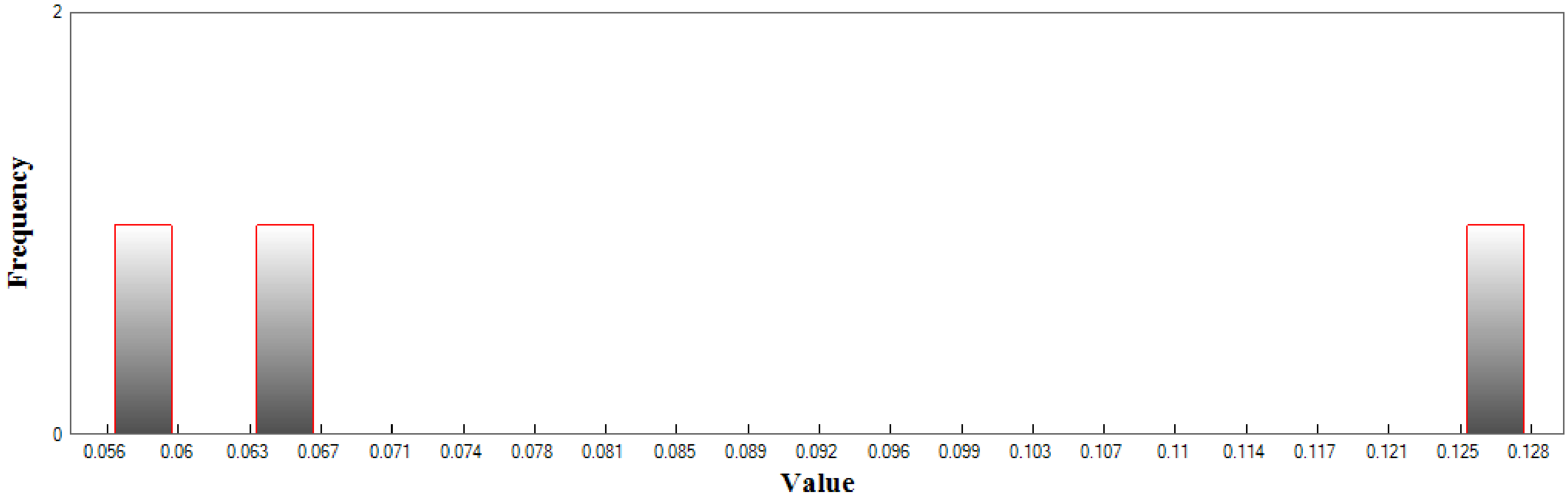
Standard Deviation DZ: 0.127

RMSE Z: 0.291

95th Percentile: 0.400

Units: Feet

Histogram



Min: 0.056

Max: 0.128

Number Of Bins: 20

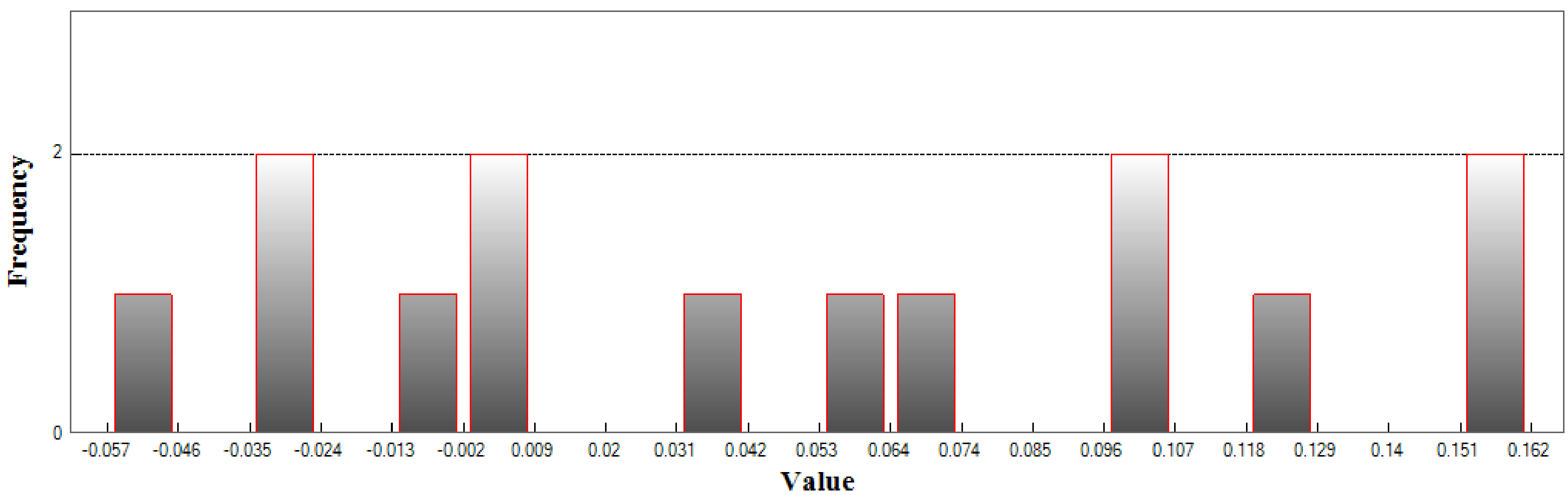
Bin Interval: 0.004

DEM (Continued)

Consolidated Vertical Accuracy

LandCover Type: ALL
Minimum DZ: -0.187
Maximum DZ: 0.534
Mean DZ: 0.164
Mean Magnitude DZ: 0.849
Number Observations: 14
Standard Deviation DZ: 0.236
RMSE Z: 0.278
95th Percentile: 0.521
Units: Feet

Histogram



Min: -0.057
Max: 0.163
Number Of Bins: 20
Bin Interval: 0.011

Raw Point cloud

Number	Easting	Northing	Known Z	Laser Z	Dz
FVA-101	239862.378	3376355.113	26.626	outside	*
FVA-102	239319.534	3367271.011	24.724	outside	*
FVA-103	250631.994	3365608.869	28.853	outside	*
FVA-104	251057.124	3376411.507	31.295	outside	*
FVA-105	263474.967	3375505.639	48.843	outside	*
FVA-106	261949.185	3365556.972	53.652	outside	*
FVA-107	295191.325	3360816.703	27.237	27.080	-0.157
FVA-108	307643.188	3361153.813	47.077	47.250	+0.173
FVA-109	302436.397	3356866.002	31.019	31.000	-0.019
FVA-110	304750.853	3352142.705	29.524	29.540	+0.016
FVA-111	281446.450	3326544.022	24.890	outside	*
FVA-112	290353.925	3327885.214	24.041	outside	*
FVA-113	296095.423	3326565.454	18.804	outside	*
FVA-114	331183.998	3317779.652	17.175	outside	*
FVA-115	330236.225	3326726.012	26.201	outside	*
FVA-116	341910.527	3325424.802	25.912	outside	*
FVA-117	344402.119	3319162.777	29.470	outside	*
FVA-118	336278.731	3313767.226	22.934	outside	*
FVA-119	338173.149	3302670.717	15.426	outside	*
FVA-131	289546.226	3324401.927	24.200	outside	*
FVA-132	335173.195	3320407.810	23.761	outside	*

Average dz +0.003
Minimum dz -0.157
Maximum dz +0.173
Average magnitude 0.091
Root mean square 0.117
Std deviation 0.136
FVA 22.9